

NON-COMBUSTIBLE AND CHEMICAL RESISTANT AIR FILTERS  
FOR  
HIGH AND LOW TEMPERATURE USE

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Introduction

After the development of the high-efficiency cellulose base filter paper and the task of getting it into commercial production was finished, Arthur D. Little, Inc. was given a contract by AEC to develop a similar high-efficiency filter that would be non-combustible, that would stand high temperatures, that would be resistant to corrosive gases and fumes, and that, if possible, would be reasonable in cost.

At the present time, the AEC working areas make extensive use of the high-efficiency space filters in which the medium is the cellulose-asbestos sheet. So far as we can learn, these filters are serving their purpose adequately, but have the one serious disadvantage of ready flammability. In many installations this can be a hazard. Moreover, cellulose softens when wet and is susceptible to deterioration from the action of some of the common chemical agents. There has always been a question of the permanence and safety of cellulose-base filters when used in and about some of the chemical laboratories and plants of the Commission. Thus, the desirability of producing a high-efficient filter of all mineral fibers has been evident for some time. Other laboratories have been engaged on this same problem or modifications of it for similar requirements of the Chemical Corps and installations of the Navy.

Obviously, a filter medium for high temperature use requires mineral fibers, of which there are only a few types available, with a number of varieties in each type. Thus, we have: glass fiber, asbestos, mineral wools, spun-fused quartz and spun alumina-silica called Fiberfrax. As was demonstrated by early experiments, an al-glass medium is possible if one can afford

the very costly grades of the finest available glass. We found early in our studies that a combination of the less costly glass fibers with certain kinds of asbestos was much more economical and almost as good. Therefore, we have worked mostly with this combination.

There are two ways in which the fibers may be laid down to form a continuous sheet: either dry forming or wet forming. Over a period of several years extending back into the period when we were developing the cellulose base paper for the Army, we have given careful consideration to both methods, but in the end have placed our emphasis on wet forming processes and the use of paper making equipment.

Glass fibers themselves do not have sufficient binding ability in a sheet to give it necessary ruggedness to withstand the rough handling incident to the manufacture of fabricated filter units. Therefore it has been necessary to use resins for binding the fibers together. The manner of doing this has been worked out and tests have indicated that after the filter unit has been fabricated, exposure to high temperature does not destroy the bond to the point where the filter paper becomes too weak for satisfactory service.

Experimental work has included the preparation and testing of hand-sheets, pilot scale paper mill runs and one full scale run on a large paper machine. Using the media produced in these mill runs, we have been able to make complete model filter units and have tested them in the laboratory for flow resistance, filtering efficiency and have found them to remain satisfactory in operation under elevated temperatures over a period of months.

Although there is still room for improvement, we believe that we have a successful filter that meets the requirements as set forth originally. There is reason to expect that filter units of this type can soon be made and sold on a commercial scale possibly at a price not too different from that of the present cellulose base filter.

A discussion of some of the details of the work leading up to this situation will give a better understanding of the present status of this filter development. Because there seems to be such wide interest in high temperature filters, a discussion of some of the development details may not be out of place.

#### Dry-Formed Filters

Since we will discuss this method of forming only briefly, it will be well to do this at the outset, and then leave the subject at this time.

The first experiments with all-mineral fiber filters were made a number of years ago on dry-formed mats of what were then the new super-fine fibers being made in the laboratories of the Fiberglas Corporation. The fibers were coated with an uncured phenolic binding resin for us, then compressed to very thin mats and cured in a heated press. These mats, especially those made with the finest triple A or double A grade of fibers, gave filtering efficiencies equivalent to or better than those of the best cellulose-asbestos papers, and they were very strong. The main objections to them were high cost, unsuitability for pleating into large compact filter unit and lack of production facilities.

After extensive study in cooperation with engineers of the Fiberglas Corporation, it was evident that a machine for producing the dry-formed mats continuously in the quantities required would be an enormously expensive installation. Moreover, it would require a long term of development and construction and the undertaking would be so large that the Fiberglas Corporation could not be expected to bear the cost. At that time, also, the more promising glass fibers for dry forming, that is, those of the very smallest diameter, were very expensive and unobtainable in quantity, and this was a large factor in the decision to switch to wet-forming methods.

Further consideration of this dry-forming problem leads some to believe that it may be possible to produce mats as a secondary operation by blowing air-borne fibers or mixtures of fibers onto a collecting drum with suitable binder material and to pass the sheet thus continuously formed through a curing oven. One of the clients of Arthur D. Little, Inc. is experimenting with a process of this kind and its application to this problem is under consideration. We do not feel, however, that the probability of final success of the operation justifies delaying the work for an indefinite period. Therefore, all of the recent effort has been devoted to wet-forming on a paper machine.

#### Wet Forming Methods

Paper making equipment already worked out is designed for wet forming of a continuous fibrous web. But paper mills vary widely depending on the kind of paper produced. There is a problem in finding a mill adapted to handling mineral fiber stock and yet flexible enough to meet our needs.

In considering a wet forming process there was a choice of working with all glass fiber or trying to make a sheet containing low cost glass fibers along with asbestos. This sheet would be constructed like A.E.C. or CWS type paper except that cellulose fibers would be replaced with glass.

An all glass sheet requires the finest grades of spun glass fibers and these are expensive. This is still true even though the prices of such fibers have been reduced greatly during the past year. On the other hand, an asbestos containing sheet needs only a relatively coarse glass fiber to form the bulk structure and to act as a support for asbestos fibers. A variation of this idea is to use very fine glass filaments supported on coarse glass fibers which form the sheet structure. However, more glass is needed to do the job than when asbestos is used and the cost again is many times higher.

We have concentrated on the use of glass and asbestos because it offered the best opportunity to provide a highly efficient mineral medium at low cost even though there is one objection that the proper asbestos might be difficult to obtain in time of war.

### Asbestos Fiber

Asbestos is a familiar fiber and the one upon which the present AEC type high efficiency filter is dependent. It is a highly effective fiber. It does nearly all of the work in the present AEC and CWS type papers, although it may be present only to the extent of about 15%. This can be demonstrated readily by testing a piece of the paper for smoke or fine dust penetration and burning out the cellulose while the paper is carefully supported on a wire screen. The efficiency of the remaining delicate web of asbestos is no different from that of the original paper.

All types of asbestos are not equally useful for high efficiency air filter media. The more useful variety has not yet been found to occur in our country or even on this continent. Domestic and Canadian asbestos are of the chrysotile variety which form long soft, silky fibers. This kind breaks down easily but forms a gelatinous dispersion in water and results in a paper that is high in flow resistance. In the recent past a determined effort was made by one of the government agencies to adapt chrysotile asbestos to filter paper manufacture but with very modest success. It is not unlikely that there are deposits of asbestos in this country that could be used but they would have to be sought out and tested as a special project. We are always examining new samples of asbestos in the hope of finding a good domestic source but funds for an active field search have not been available up to the present time.

The asbestos useful for filter manufacture is an iron and soda containing silicate. It is the blue asbestos found in Bolivia, South Africa and to a lesser extent, in Australia. When beaten in water the fibers break down into cleanly formed microscopic needles.

In one sense it has been most fortunate that blue asbestos works so well as a filter medium ingredient. Until recently it has been the only material capable of providing high filtering efficiency at low flow resistance. It is still by far the cheapest means of doing this. While there are certain recognized disadvantages associated with the use of asbestos we have stayed with it - purely as a matter of economics. AAA glass fiber now may be had at \$3.50 per pound. One pound of cleaned blue African asbestos costs about 40 cents per pound and does the work of two pounds of AAA glass fiber.

#### Other Mineral Fibers

In addition to glass and asbestos, we have considered bulk mineral wool and the new alumina-silica fiber developed by the Carborundum Company. Mineral wools (other than glass) are coarse, tend to have a high content of slugs and shot and are generally undesirable. Fiberfrax, the Alundum Co. product, is about equivalent to the glass fiber of the same diameter as a high efficiency filter. The material that we examined had a high proportion of shot or sandy particles. It was expensive and unavailable in quantity. The only advantage that this fiber appears to have is that it can be used at very high temperatures. Its softening point is above 1700°C. That leaves us only glass and asbestos to work with.

#### Glass Fiber

Glass fiber is a manufactured product made of materials which are in good supply. The table following is a list of present glass fiber manufacturers. Glass fiber of a given grade is uniform and dependable in its properties. It can be obtained perfectly clean and requires very little preparation in a wet process. These points make glass very attractive for use in high efficiency

LEADING COMPANIES IN GLASS FIBER PRODUCTION

Sales, 1950  
(Millions of Dollars)

Notes

Plants and Products

1. Owens-Corning Fiberglas Corp.	78.3	Newark, O., - wool, mat, marbles Kansas City, Kan. - wool, mat Santa Clark, Calif. - wool, mat Ashton, R.I. - yarn, staple, rovings Huntington, Pa. - yarn, staple, mat Anderson, S.C. - yarn	Anderson plant expected completed by April 1952
	(97.4 in 1951)		
2. Glass Fibers, Inc.	3.3	Waterville, O. - yarn, mat Defiance, O. - glass wool	Expansion plans to double capacity of both plants
	(1.45 to May 1951)		
3. Libbey-Owens-Ford Glass Co.	170.0	Parkersburg, W.Va. - yarn super-fine wool	Plant started operation 11/16/51
4. Tilo Roofing Co., Inc. Glasfloss Div.	10.2	Hicksville, L.I. - rovings, bonded mats	Became division of Tilo on 12/10/49
5. American Air Filter Co., Inc.	12.1	Louisville, Ky. - glass fiber air filters	Mfg. by a subsidiary, Famco, Inc.
6. Gustin-Bacon Mfg. Co.		Kansas City, Kan. - insulating mats	New plant project at Kansas City
7. Perrault Glass Fiber Corp.		Tulsa, Okla. - pipe wrap	
<u>FUTURE PRODUCERS</u>			
Pittsburgh Plate Glass Co.	339.4	Shelbyville, Ind. - superfine and strained glass fiber	To start operations in Fall 1952
Ferro Corp.	33.4	Nashville, Tenn. - unknown	To start operations in Fall 1952

filters. However, we have found that without asbestos the very finest glass fibers must be used in order to do a comparable job. Unfortunately, the cost of glass is an inverse function of fiber diameter. Following are some recent figures.

<u>Fiber Type</u>	<u>Filament diam. microns</u>	<u>Fiber price dollars/lb.</u>
B	3.2	1.20 - 0.80
A	2.3	1.50
AA	1.3	2.50
AAA	0.7	3.50

These fibers are in the class known as "superfine" or the Aerocor product (Fiberglas Corp.). They are made in a two step process in which a coarse filament is first drawn, then this further reduced to a very fine diameter in a high temperature flame. When reduced to a one micron fiber a pound of glass is extended to a filament 145,000 miles in length.

The prices for superfine fiber have been reduced greatly in the past year. We have been told that Fiberglas Corp. now has facilities for large scale production of superfine so that it is now obtainable in tonnage lots.

Moreover, Fiberglas has been developing a new low cost process for making fine fiber in bulk and it was hoped that this would meet the filter needs of A.E.C. Upon examination it was found that the samples as offered contained so much unusable and objectional shot that it gave little price advantage over the higher grade fibers and would be troublesome to prepare for use.

In another spinning process, glass is drawn continuously at a high rate of speed onto a rapidly revolving mandrel. This produces "continuous filament" yarn which is the basis for the many textile applications of filament glass. One grade of continuous filament fiber measures about twice the diameter of "B" fiber. It costs about \$1.00+ per pound and can be obtained as a roving that is readily cut by mechanical means. However, the fibers are coated with a preparation that must be removed before they can be handled readily in a wet process.

Another product, insulation wool, is the least expensive of all the glass fibers although it has a diameter some ten times that which we prefer. Despite the fact that we have made some surprisingly effective filters with this fiber (and asbestos) they were lacking in flexibility and we regard such coarse fibers as unsuitable for high quality air filter media.

Nearly all of our work has been done with "B" fiber in combination with asbestos and suitable binders.

#### Laboratory Work

Development work in the paper field is guided by the preparation and testing of hand made sheets. We use standard paper laboratory equipment consisting of a small beater, freeness tester, handsheet mold and drum drier. In addition we have a standard Chemical Corps D.O.C.H.E smoke penetration tester.

The following procedure was worked out in the laboratory and found to give consistently good results:

The glass was reduced in a beater at a consistency of about 1/2% until a proper fiber length was attained. Since the fibers cut in this way are of random length, only an approximate figure can be given.

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We might say that they range in length up to about 3/16 inch. As a control means, it was found that the freeness tester could be used. In beating or breaking down glass fiber only a light roll pressure is needed.

A cationic urea formaldehyde resin is added to the glass - preferably in the beater. This serves the double purpose of preventing the seizure of adjacent fibers and also conditions the glass surface to receive a binding resin that is added later. At first we made our own dispersing resin but we found a commercial resin that does just as well or better.

Asbestos is beaten in plain water until it is opened up to a freeness found to be suitable for that particular lot of fiber. Again the freeness tester is used to control the amount of beating.

A quantity of the glass fiber slurry is then blended with the proper amount of asbestos slurry, the binding resin added in the form of aqueous emulsion, and the sheet cast in the hand mold.

Upon removal from the mold the sheet is blotted damp dry with just a little pressure - and finally dried on a steam heated drum dryer.

In the DOP penetration tests the handsheets match the performance of A.E.C. or CWS paper.

There is a characteristic of high efficiency air filter media which we have called the "Velocity slope." D.O.P. penetration of the media nearly always changes with air flow rate; usually the penetration decreases with flow rate. The effect varies with the kind of medium and seems to be influenced by the gross fiber. In this respect the glass-asbestos sheet has a better behavior than the present cellulose-asbestos papers.

It is a long step between making successful handsheets and getting off a run of paper in a mill. Making good handsheets only tells us that it might be possible to produce the medium on a commercial paper making machine.

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Experimental Runs

Our first attempt to make glass-asbestos medium on a papermaking machine was at New York State University, School of Forestry, in Syracuse, New York.

Because it is necessary to make frequent tests on the sheet as it comes from the machine, it is necessary to have a dioctyl phthalate smoke penetration tester on hand during a paper mill run. Normally, this kind of equipment is cumbersome and therefore almost of necessity stationary. Since we knew that a number of experimental mill trials had to be made, perhaps at different mills, we designed and built a portable DOP tester of such compact dimensions that it could be carried in two suitcases. This unit proved to be invaluable in our later work.

The trial at Syracuse was unsuccessful. We encountered a very serious foam problem in the beater (due to the dispersing agent) and because the centrifugal recirculating pumps whipped air into the stock even when it could be prepared in the beater. Foaming is bad in that the air bubbles attach themselves to the glass fibers causing them to float and to agglomerate. Once this occurs, it is very difficult to get them redispersed.

We were convinced that the mill at Syracuse was unsuited for our purpose. Furthermore a run required about 1000 pounds of fiber and this made the cost of experiments much too high.

After several paper mills had been considered, we visited the Riegel Paper Corporation at Milford, N.J., and learned that they had a small experimental machine that could be made available to us. This company proved to be very cooperative and so helpful on the project that all of our subsequent experimental plant work has been done using their facilities.

Riegel's experimental Fourdrinier machine proved to be ideal for our purpose. It is small (25" wire width) and can be run very slowly so that as little as 60 pounds of stock can be run per hour. This little mill is staffed by personnel accustomed to experimentation. Finally, and this is important, long experience on the part of Riegel made it feasible to foretell the approximate behavior of any furnish on their commercial machines once it had been run in the experimental plant.

Since last October some half dozen runs have been made. For most of them about 200 pounds of fiber were prepared. This gave enough stock to permit a machine run of about 3 hours.

Our experience at Syracuse taught us to keep foam producers out of the beater and since the experimental mill used piston pumps for recirculating stock, there was little trouble with foam.

The only objection to the small machine was that it produced a trimmed sheet but 19" wide. Another five inches would have permitted us to turn out paper wide enough to build full size filters. However, the stock we did produce allowed us to build and test small filter units 8" x 8" x 6" deep.

We learned to make acceptable paper on the experimental machine and felt encouraged to try a commercial scale run.

#### Commercial Machine Run

On August 8 of this summer, Riegel provided the use of a commercial Fourdrinier machine over which we ran a 4000 pound batch of glass-asbestos furnish.

Some modifications had to be made on the machine to accommodate our run. Our paper forms best from a highly dilute stock. This required running the machine at the slowest possible speed. Means were also provided for adding

additional asbestos to the machine head box for adjustment of asbestos content in the sheet. Changes were made to allow certain unneeded parts for the machine to be bypassed.

In all, about 900 pounds of glass paper were reeled and of this 415 pounds were later slit and re-reeled for shipment to Cambridge, Mass.

In general, we felt that this was a good run. Complete success in a first run is always a hope, but one that is seldom realized. The paper formed surprisingly well on the wire and at a speed that was high for such material. The sheet handled well on all parts of the machine except the wind-up reel which was of the wrong type.

We are encouraged to believe that glass-asbestos air filter medium produced on standard papermaking equipment will provide at the least cost non-combustible, high efficiency, air filters with improved resistance to moisture and corrosive atmospheres.

Very recently there has come to our attention a source of very inexpensive glass fiber that may make the cost of our medium equal to or even less than the present low temperature papers.

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